

# **Turbine Air-Flow Test Rig CFD Results for Test Matrix**

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- Outline
  - TAFT Background
  - Design Point CFD
  - TAFT Test Plan and Test Matrix
  - CFD of Test Points
  - Conclusions



- Background
  - TAFT (Turbine Air-Flow Task) test rig
    - Based on Integrated Power-head Demonstrator program (IPD)
    - TAFT is 1.42 super-scale of IPD Lox Turbine
  - Initial CFD Simulations performed Spring 2002
    - CFD Simulations performed for design point
    - Solutions used to determine
      - Flow Environment
      - Instrumentation Locations
  - TAFT testing began Spring 2003
    - Testing will include 4 configurations
      - 13 nozzle, 17 blade geometry with “near” axial gap
      - 13 nozzle, 17 blade geometry with “far” axial gap
      - 22 nozzle, 17 blade geometry with “near” axial gap
      - 22 nozzle, 17 blade geometry with “far” axial gap



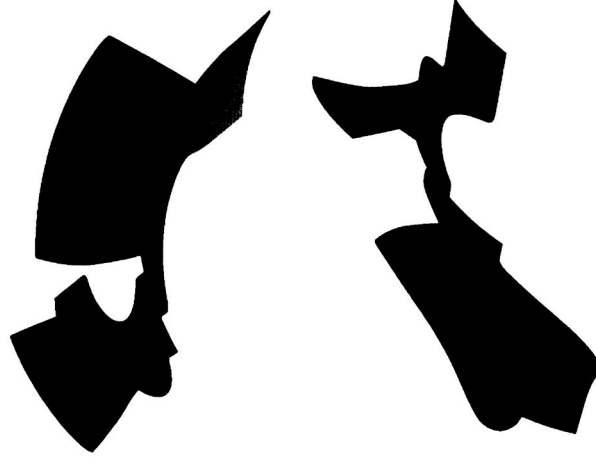
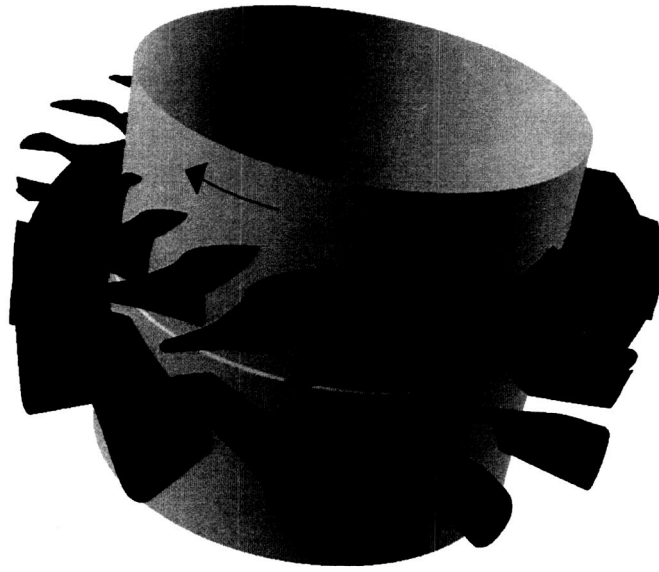
- Initial CFD Solutions

- CFD Tools

- Corgrid: Grid Generator

- Corsair: Unsteady, Parallel, Turbomachinery Analysis CFD Code

- Grid

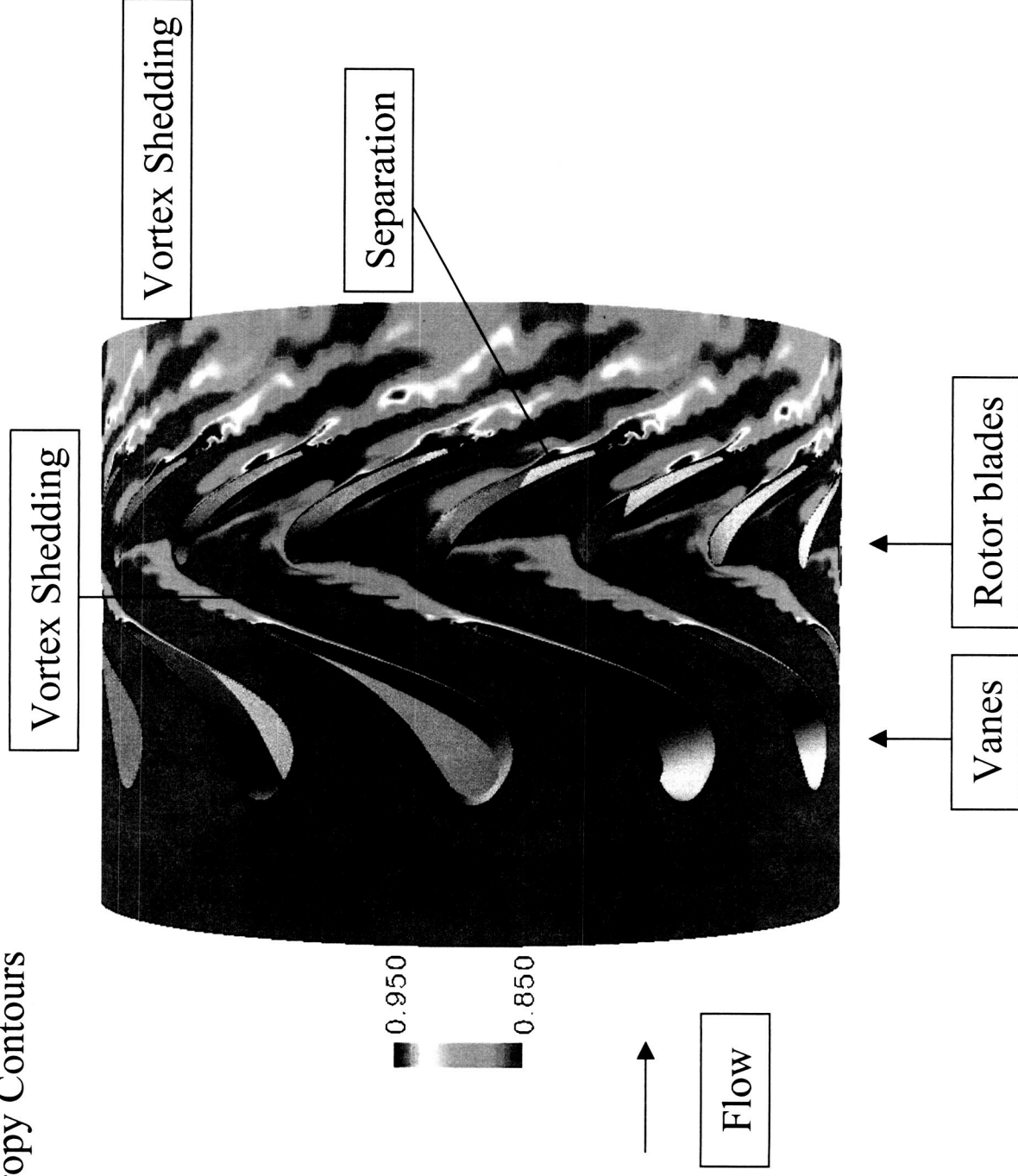


|                | Vane-1    | Rotor-1   |
|----------------|-----------|-----------|
| O-grid         | 181x51x41 | 181x51x41 |
| H-grid         | 123x61x41 | 142x57x41 |
| # of passages  | 2         | 3         |
| Total grid pts | 1,372,188 | 2,130,975 |



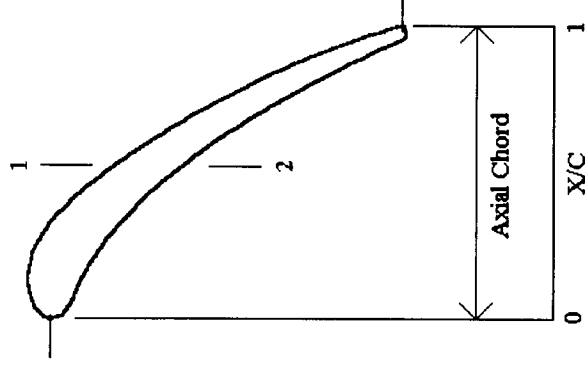
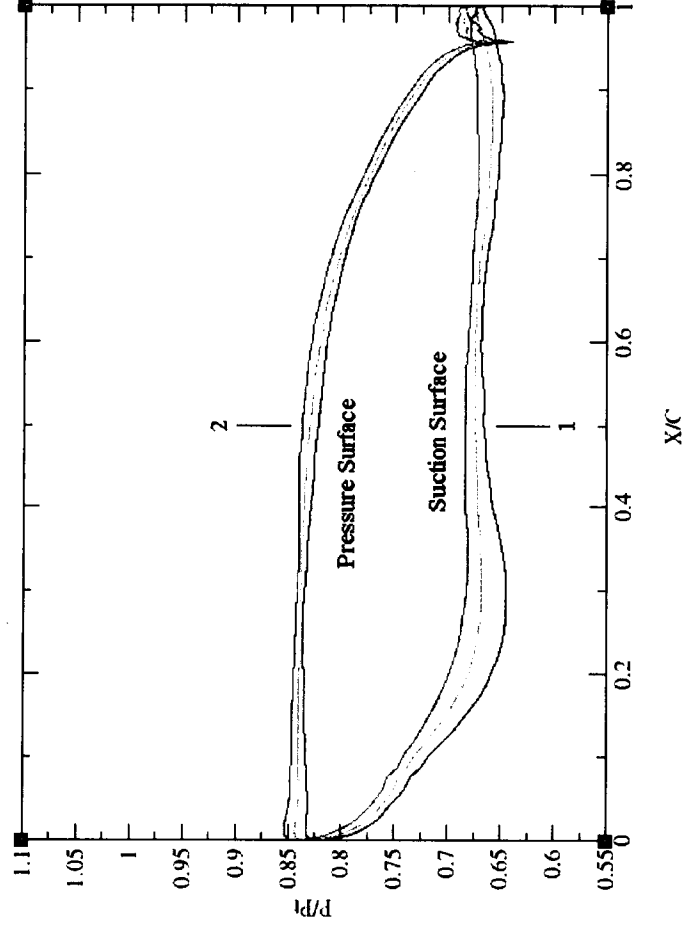
- Initial CFD Solutions

- Entropy Contours



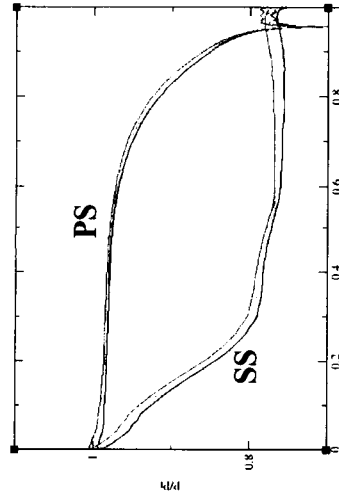
- Initial CFD Solutions

- Solutions

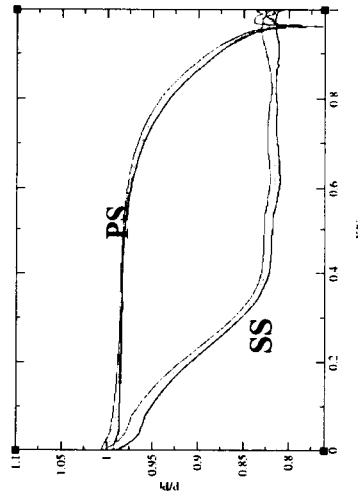


# •CFD Solutions

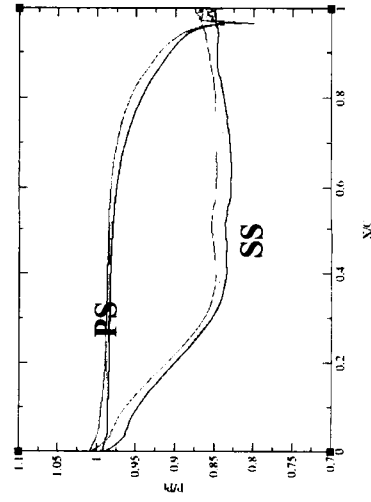
- Vane Pressure Envelopes



11% Span



50% Span



89% Span

PS : Pressure Surface

SS : Suction Surface

— Maximum

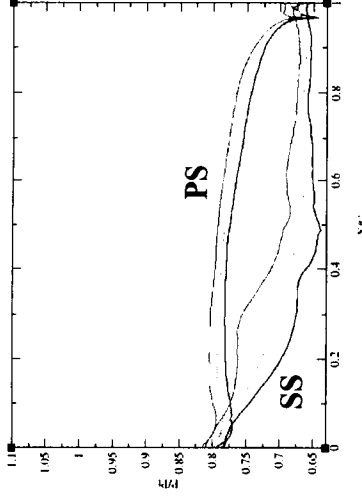
--- Time Average

... Minimum

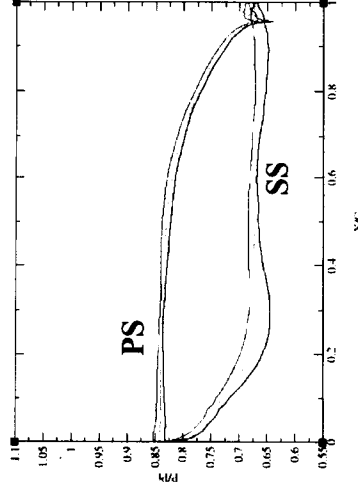


# •CFD Solutions

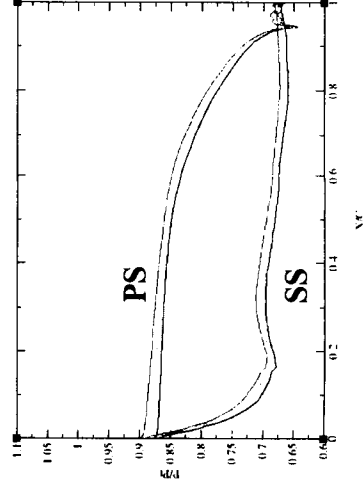
## •Rotor Pressure Envelopes



11% Span



50% Span



89% Span

PS : Pressure Surface  
SS : Suction Surface

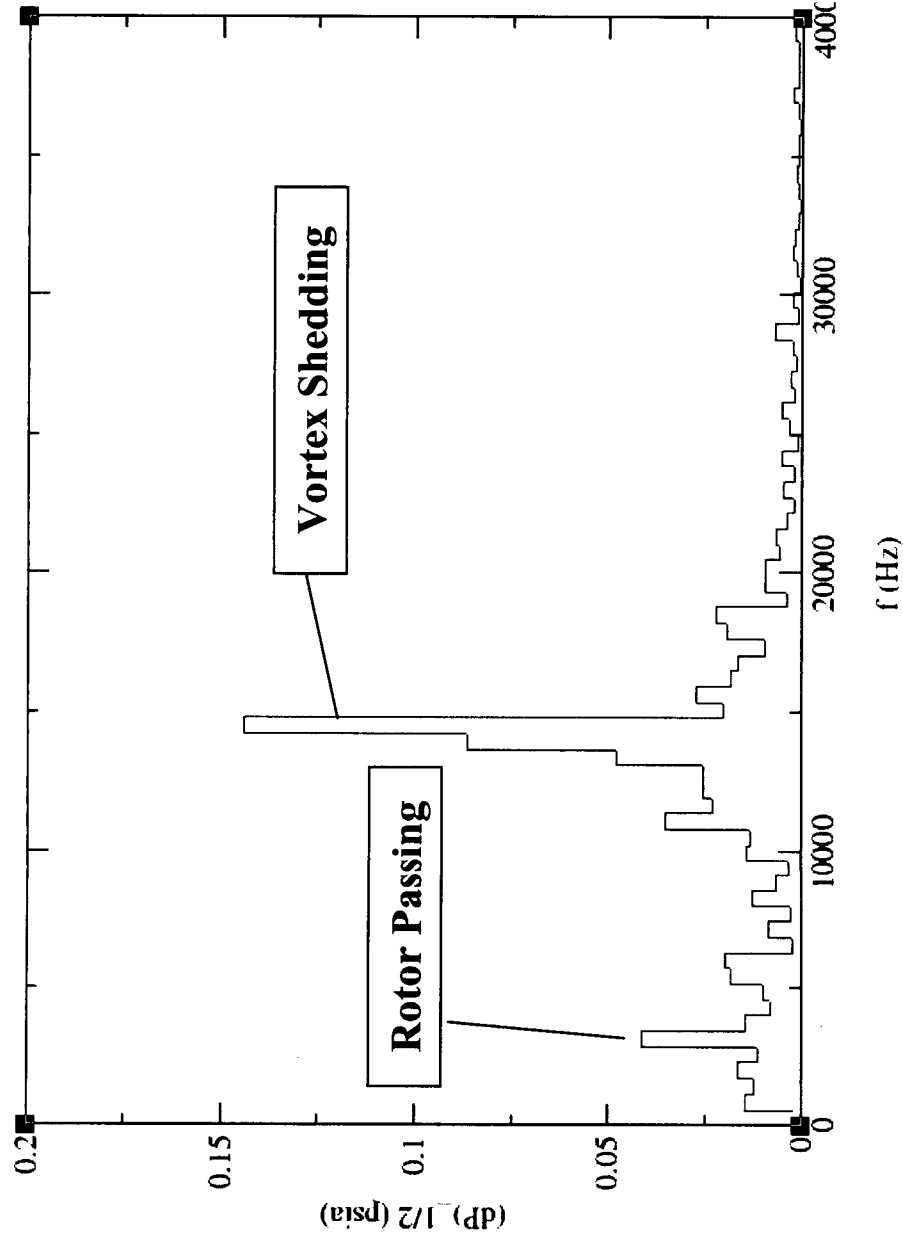
— Maximum  
— Time Average  
— Minimum





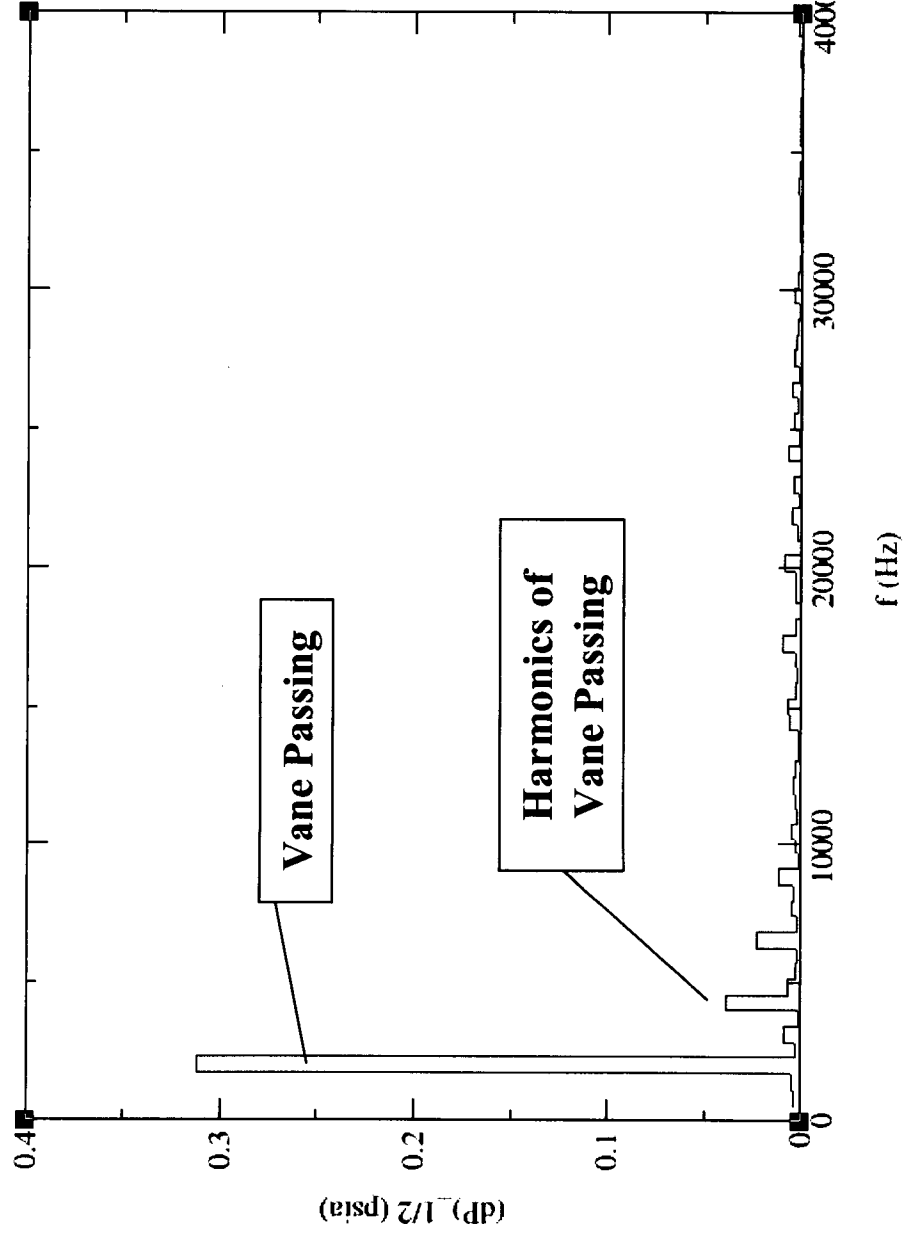
- CFD Solutions

- Vane trailing edge spectrum at mid-span



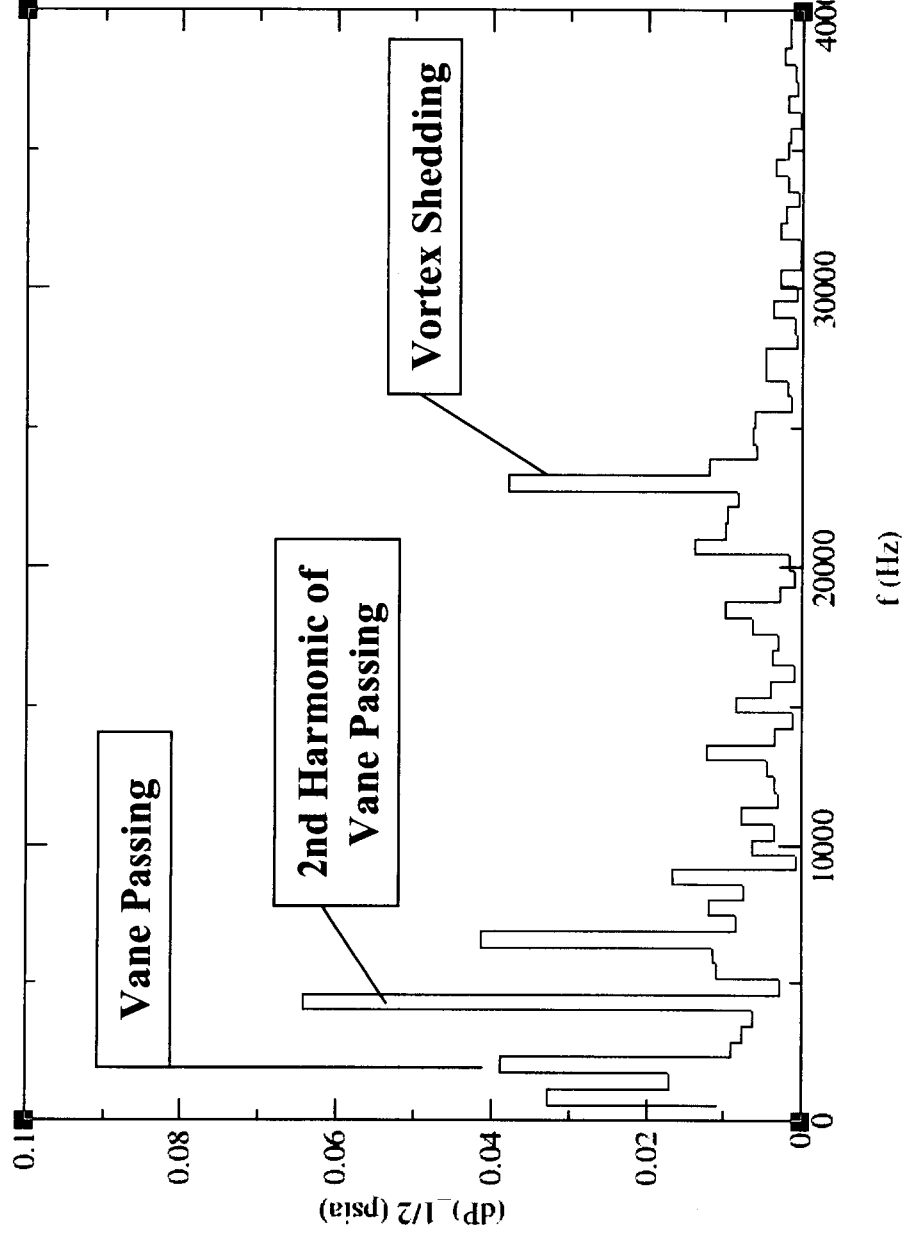
- CFD Solutions

- Rotor leading edge spectrum at mid-span

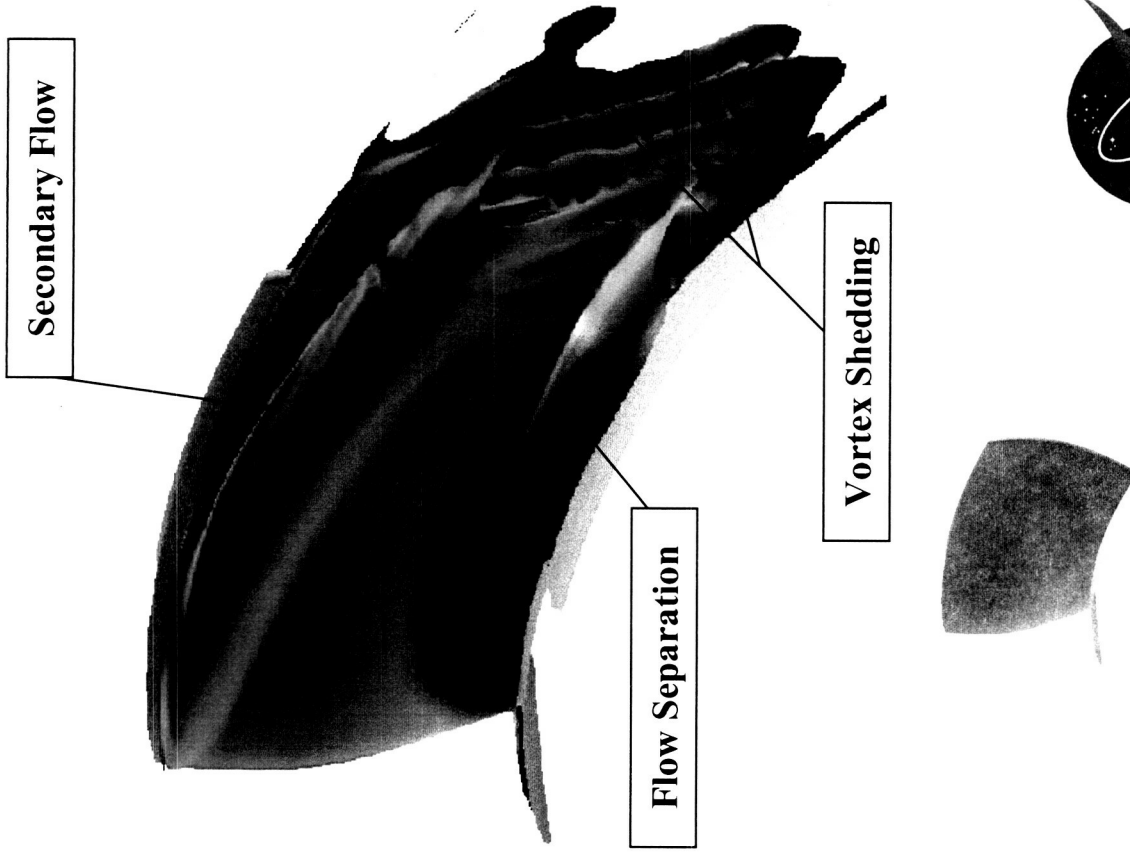
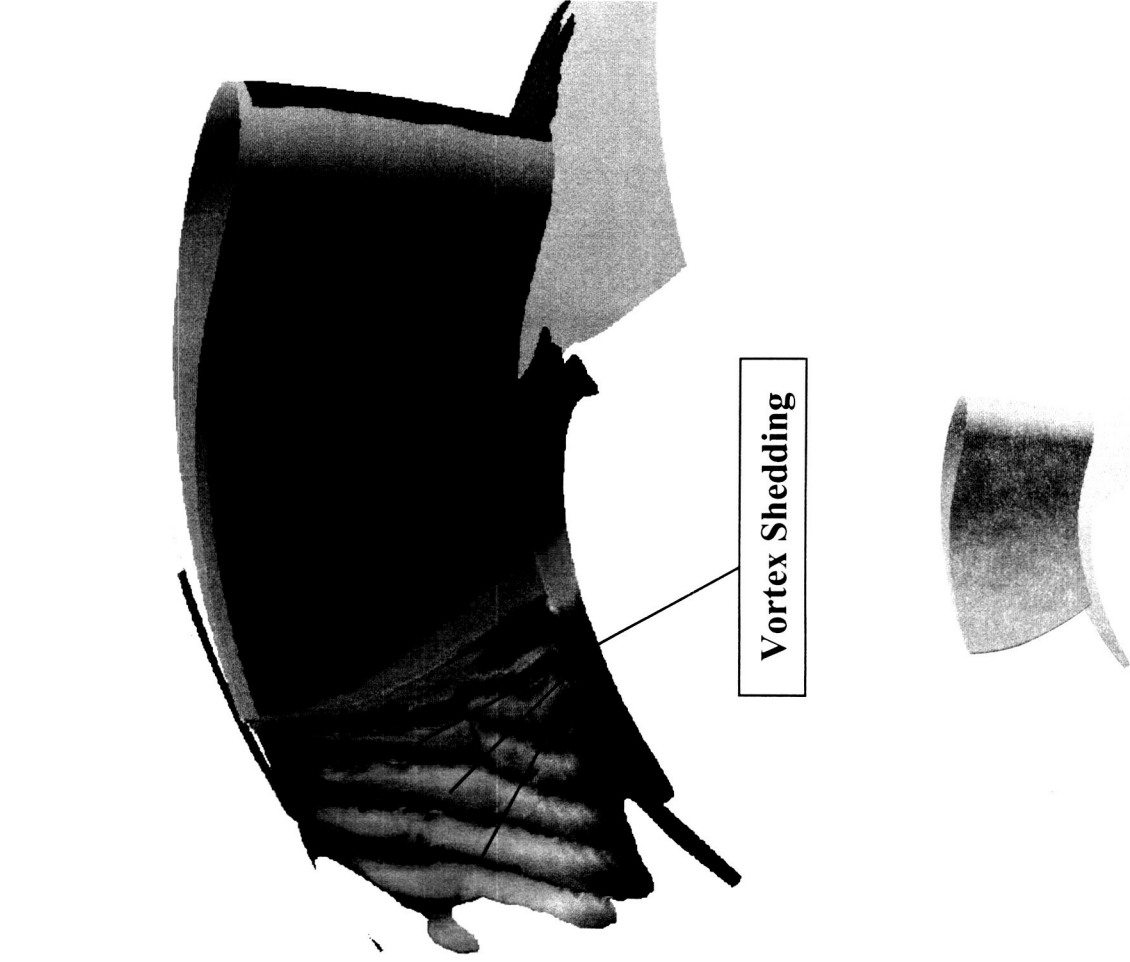


- CFD Solutions

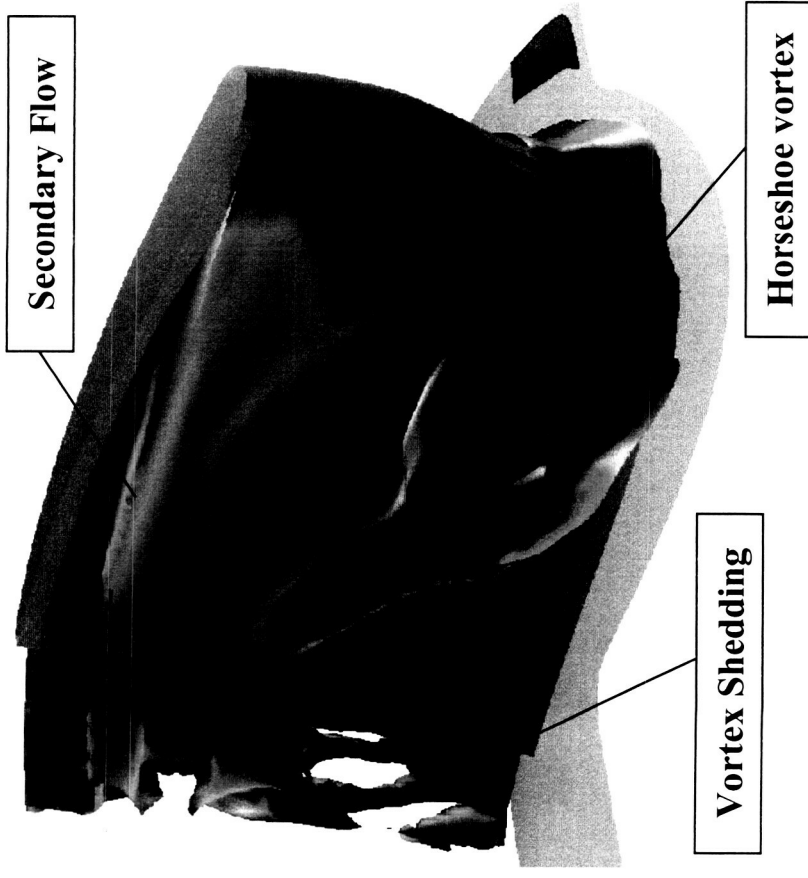
- Rotor trailing edge spectrum at mid-span



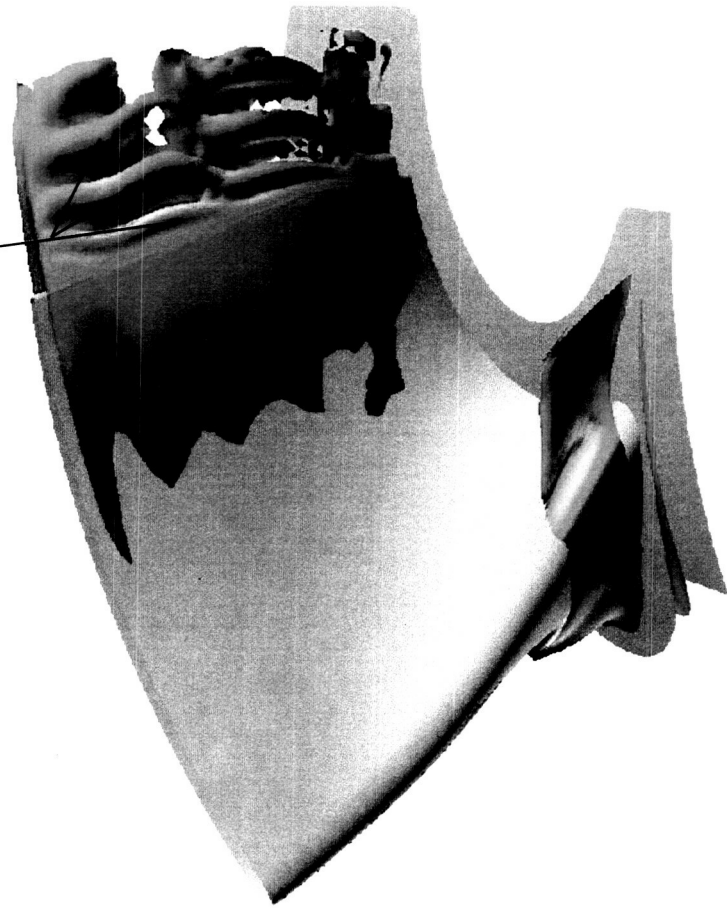
- Iso-Surfaces of Entropy for the Nozzle Vane



# • Iso-Surfaces of Entropy for the Rotor

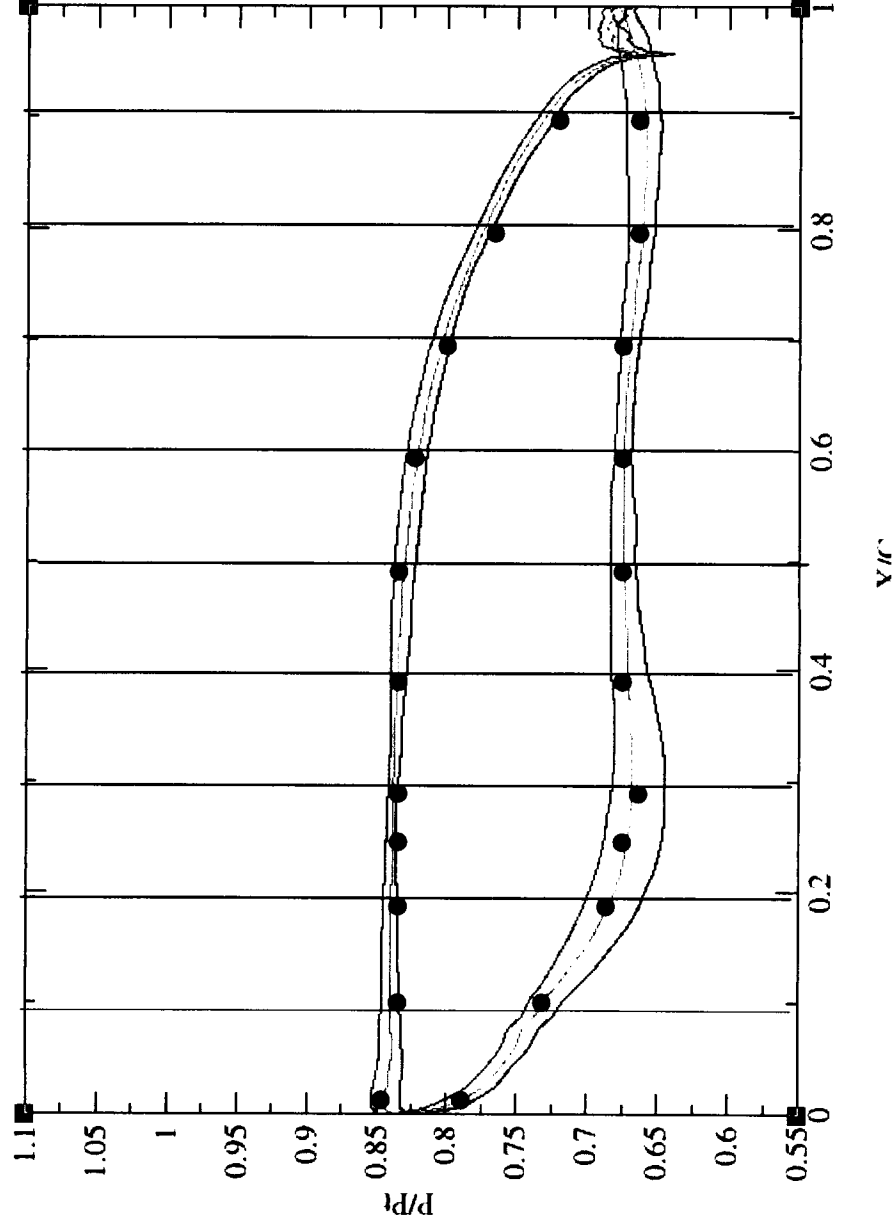


Vortex Shedding



# Instrumentation Locations

- CFD to determine instrumentation locations for test



Leading edge: pressure and suction side(as close to i.e. as possible)

10% axial chord : pressure and suction side

20% axial chord : pressure and suction side

25% axial chord : pressure and suction side

30% axial chord : pressure and suction side

40% axial chord : pressure and suction side

50% axial chord : pressure and suction side

60% axial chord : pressure and suction side

70% axial chord : pressure and suction side

80% axial chord : pressure and suction side

90% axial chord : pressure and suction side

( 22 Sensors total at 50%span)

Maximum  
Time Average  
Minimum



- TAF<sup>2</sup> test matrix

- Taft testing began April 2003
- Testing will provide good validation database for CFD and Meanline analysis codes

TAF<sup>2</sup> Test matrix

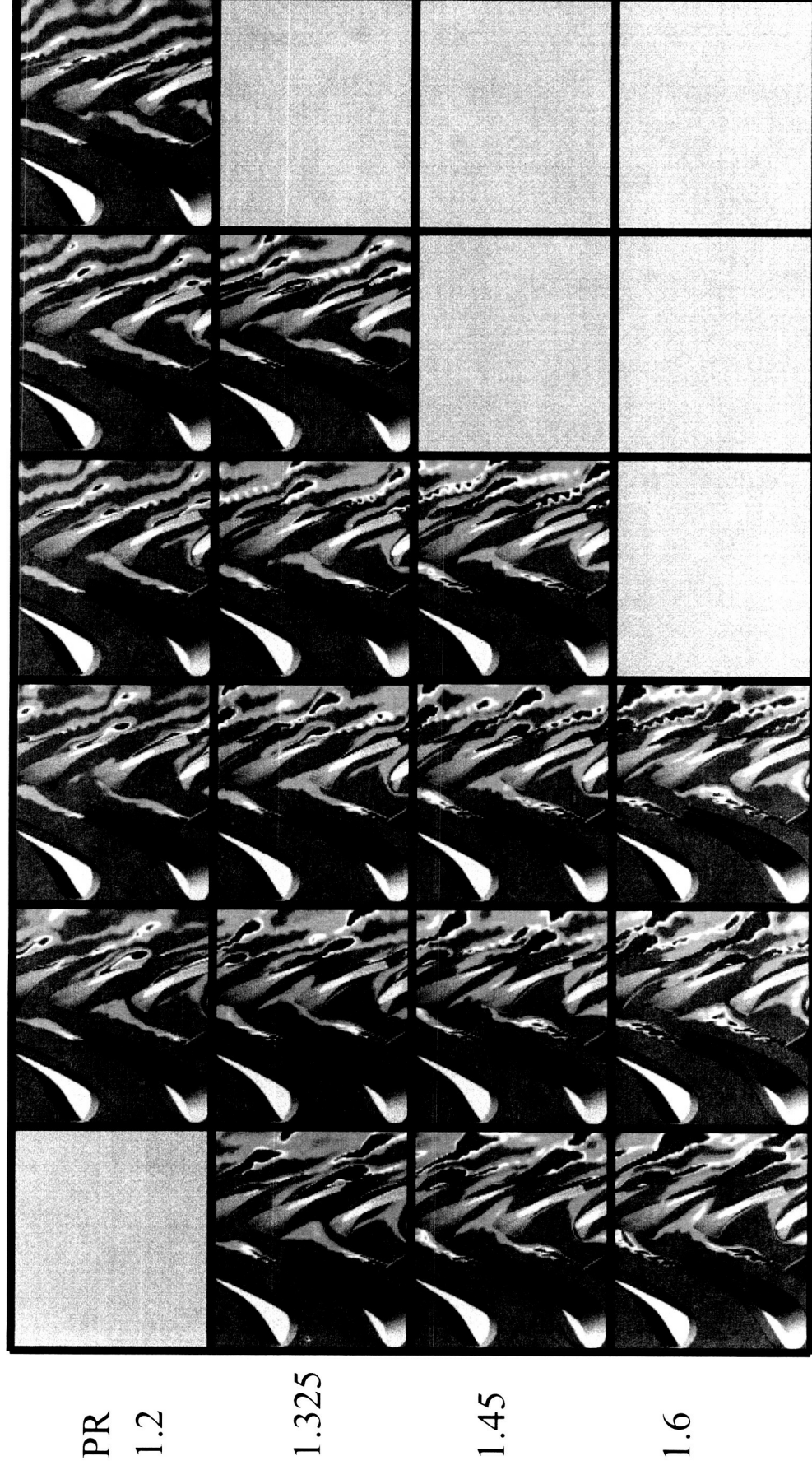
| U/C0<br>PR | .440                                 | .500                                 | .579                                  | .658                                  | .729                                  | .8                                  |
|------------|--------------------------------------|--------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|-------------------------------------|
| 1.2        |                                      | 6122 rpm 19.31<br>lb/sec 124.6 ft-lb | 7091 rpm 19.34<br>lb/sec 112.5 ft-lb  | 8058 rpm 19.35<br>lb/sec 100.1 ft-lb  | 8925 rpm 19.38<br>lb/sec 89.4 ft-lb   | 9794 rpm 19.46<br>lb/sec 79.5 ft-lb |
| 1.325      | 6646 rpm 22.49<br>lb/sec 192.3 ft-lb | 7552 rpm 22.50<br>lb/sec 179.0 ft-lb | 8746 rpm 22.53<br>lb/sec 161.6 ft-lb  | 9939 rpm 22.56<br>lb/sec 143.9 ft-lb  | 11011 rpm 22.60<br>lb/sec 128.7 ft-lb |                                     |
| 1.45       | 7589 rpm 24.47<br>lb/sec 238.6 ft-lb | 8623 rpm 24.48<br>lb/sec 222.2 ft-lb | 9986 rpm 24.52<br>lb/sec 200.6 ft-lb  | 11348 rpm 24.56<br>lb/sec 178.7 ft-lb |                                       |                                     |
| 1.6        | 8476 rpm 25.97<br>lb/sec 282.3 ft-lb | 9635 rpm 26.0<br>lb/sec 262.9 ft-lb  | 11154 rpm 26.03<br>lb/sec 237.3 ft-lb |                                       |                                       |                                     |



# • TAFIT test matrix CFD Solutions

- Absolute entropy contours shown below

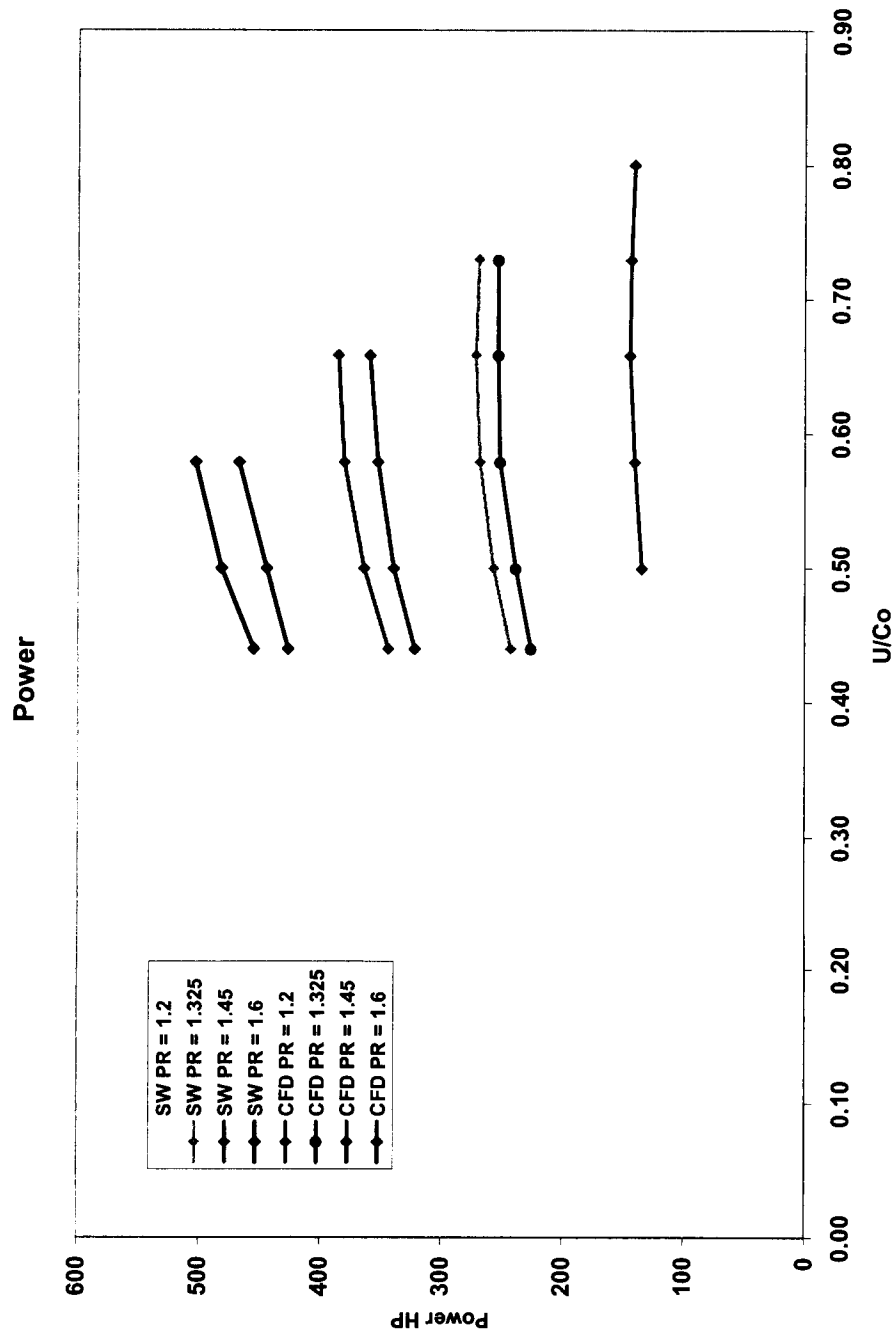
U/Co    0.440    0.500    0.579    0.658    0.729    0.800





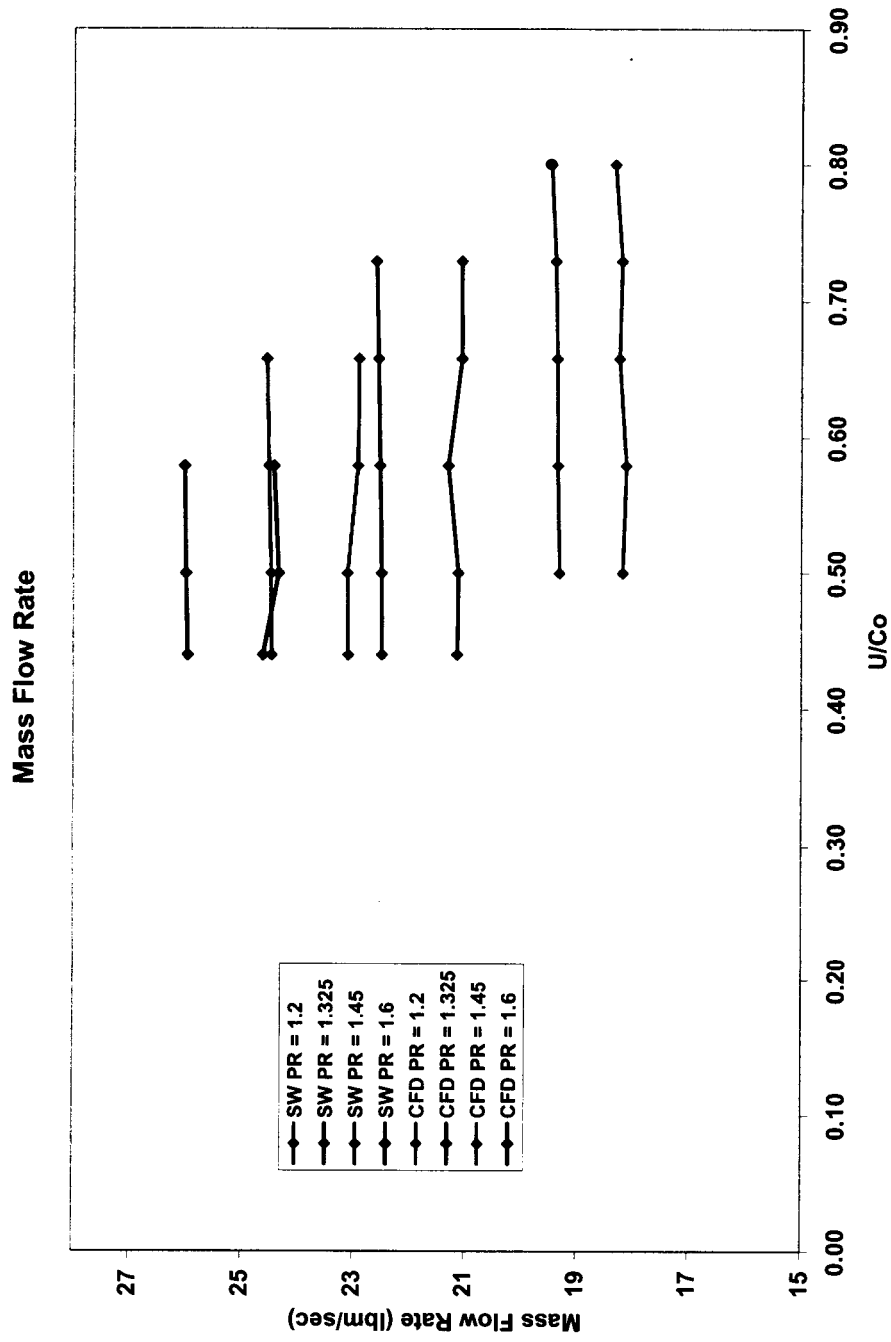
# • TAFI test matrix CFD / Meanline Comparison

- Meanline XXXX



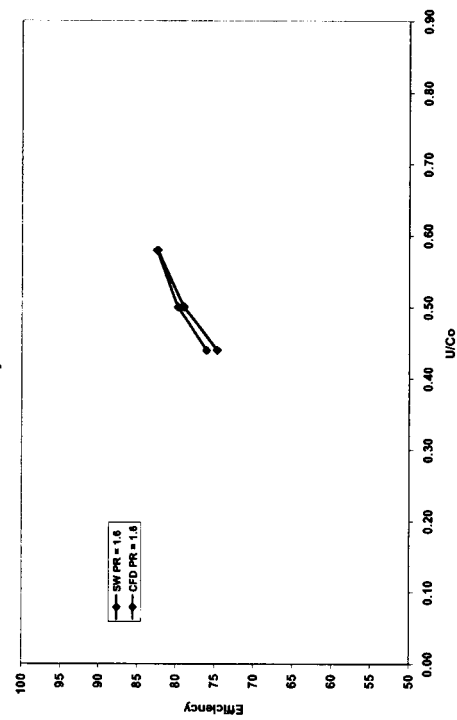
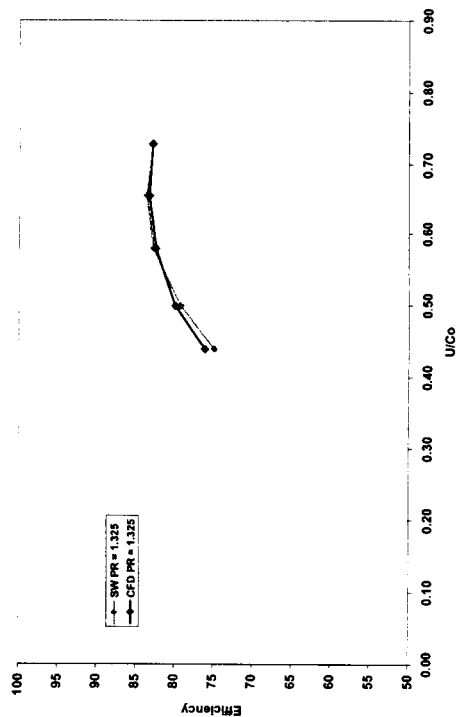
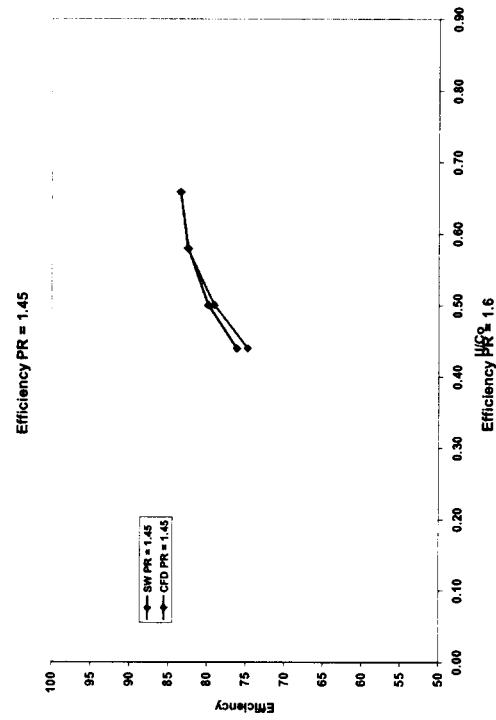
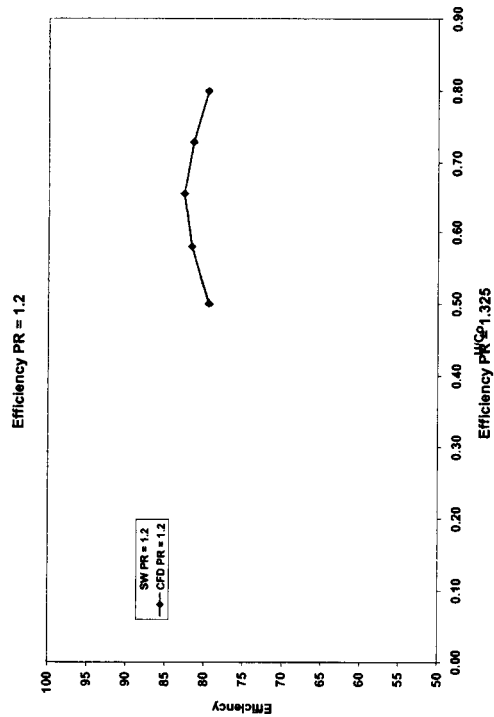
# • TAFt test matrix CFD / Meanline Comparison

- Meanline XXXX



# • TAF test matrix CFD / Meanline Comparison

- Meanline XXXX



- Conclusions

- Simulations Completed for 13 Vane case / Design Axial Gap
- Currently interrogating solutions
- Testing for 13 vane configuration to begin May 2003
- CFD Shows higher mass flow than meanline
- Initial testing suggests (Preliminary):
  - CFD shows the higher mass flow than Meanline and Test
  - Meanline Codes flow 3% more than Test rig
- Test will provide excellent validation / comparison tool for both CFD and Meanline analysis tools
- Final Comparisons will be presented when complete

